Nursing Manpower Allocation in Hospitals
Staff Assignment Vs. Quality of Care

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Dilemmas

- Can a hospital establishment be managed like an industrial or commercial service organization?
  
  In case we have a partial yes, than..

- Can Industrial Engineering tools be used to enhance productivity measures in daily management (like it does to industry)?
  
  If possible, than..

- Can the largest workforce in this operation - the nursing force, provide better performance rates, according to economical criteria?
  
  If yes, than..

- Can an IE based methodology be used, to determine optimal nursing assignment in hospitals, to provide better quality care?
Dilemma – in practical terms

- Can a pre-calculated performance time be a factor, to enhance anonymous patient’s quality care?

  or

- Can quality of nursing care be presented by calculated operational time - for nursing activities, at any given clinical ward in hospitals?

  and

- Is it practical to determined the best ‘mix of nurses’ for a random ‘blend of patients’ in a ward?

- Can we then provide pre-determined values for quality of service?
There is an enormous demand for nurses in the immediate future, much more than can and will be available

Nurses FTE’s (Full Time Equivalent) doesn’t satisfy operational requirements

Nursing assignment are planed by the ‘head nurse’ according past experience – ‘guts feelings’

There is a non homogeneous distribution of work content among nurses

Quality of ‘nursing job’ does not play any factor in determination of nursing assignments

Forecasting the ward’s patients blend - doesn’t exist
Allocating a fixed number of nurses per shift while patient's number and complexity vary from shift to shift

### Nursing allocation pattern - Internal ward C, Sheba Med. Center

<table>
<thead>
<tr>
<th>Day / Shift</th>
<th>Morning</th>
<th>Evening</th>
<th>Night</th>
<th>Real need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>Monday</td>
<td>5</td>
<td>3.5</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>Tuesday - Thursday</td>
<td>5</td>
<td>3.5</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>Friday</td>
<td>4.5</td>
<td>3</td>
<td>2</td>
<td>?</td>
</tr>
<tr>
<td>Saturday</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>?</td>
</tr>
</tbody>
</table>
Objectives of study

- Develop a nursing manpower allocation model which deals with workload, assignment and best fit between patient’s demands and nurses availability - in clinical wards

- Establish a quantitative method that relates to productivity issues and to quality of care - for nursing activities
Method

- Redefine nursing activities to allocate productive ways to deal with dynamics of patients variability

- Define nursing skills suitable for proper handling at different nursing levels for various patient’s needs

- Determine work load and nursing activities in a quantitative way - on basis of performance measurement

- Exercise findings and study approach in 2 Internal Med. Wards and 1 Surgery Ward in Sheba Med. Center

- Use simulation procedures to forecast best nurse and patient mixture – create a decision tool for management
Method

- Nursing allocation policies definition
- Patients classification
- Forecasting patients blend
- Establishing time data base for nursing activities in target unit

Simulation

Influence of the nursing FTE’s on the nursing quality of care

Converting the simulator results to a nursing FTE’s
Design of study

- Develop a patient’s classification routine
- Establish time data base for nursing activities, to target departments
- Develop a forecasting patients blend program
- Introduce a nursing allocation policies
- Simulate patients needs to nursing assignments along 4 steps
- Integrate quality of treatment in a manpower allocation equation
Patients classification

- Patient’s needs, in a time for care terms, varies as result of ‘nursing complexity’
- Nursing complexity, defines the scope of patient’s needs - equivalent to a diagnosis, related to the difficulty and measures of needed nursing care
- A five level scale to nursing complexity:

  **Special nursing care** – A ventilated patient that his condition fits to emergency unit

  **Complex nursing care** – A patient that needs an intensive nursing care

  **Full nursing care** – A patient that is confined to his bed or depended on the nursing staff in implementation of his major daily activities

  **Partial nursing care** – A patient with a chronic disease that is not depended on the nursing staff in implementation of his daily activities

  **Minimal nursing care** – A patient that his nursing needs are fulfilled by a routine activity of the nursing staff
Nursing allocation policies, theoretical

1 - Policy

N - Policy
version #1

N - Policy
Version #2
Nursing allocation policies (cont.)

M - Policy

W - Policy
The daily nursing work is a very complex work which characterized with a great random activities.

More than 65% of the work performed by a nurse influenced by others, including physicians, administrators or professionals from other disciplines.

On average 74 different activities are executed by a nurse in one shift. (Murphy et al., 1997)

Establishing a nursing time values (for core activities) can be made by the following techniques:
- Time study
- Work sampling
- PMTS
- Evaluation
Collecting core time values
# Procedures for collecting time data

Classical approaches vs. current and proposed state

<table>
<thead>
<tr>
<th>Technique</th>
<th>Characte rization</th>
<th>Applied or used</th>
<th>Level of accuracy</th>
<th>Impleme ntation</th>
<th>Operative value</th>
<th>Managers tool ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time study Incl. PMTS</td>
<td>classic approach</td>
<td>was not done</td>
<td>high</td>
<td>very slow</td>
<td>good</td>
<td>Yes (for pros.)</td>
</tr>
<tr>
<td>Work sampling</td>
<td>classic approach</td>
<td>done in past</td>
<td>low</td>
<td>varies</td>
<td>problematic</td>
<td>problematic</td>
</tr>
<tr>
<td>Evaluation</td>
<td>current state</td>
<td>used often</td>
<td>intuitive</td>
<td>fast</td>
<td>bad</td>
<td>non quantitative</td>
</tr>
<tr>
<td>Simulator</td>
<td>proposed state</td>
<td>was not done</td>
<td>based on data</td>
<td>fairly fast</td>
<td>justifies itself</td>
<td>promising</td>
</tr>
</tbody>
</table>
The core activities approach

- Unlike traditional industries, measuring outputs in the health care industry is very difficult.
- High variability, random and frequency of calls for nursing care, contribute to complex definitions for ‘quality of care’ - such will not be adopted.
- A different approach is proposed, based on “time for core activities” which will spread along time from **selected activities** to **all activities**.
- The term for ‘quality of nursing care’ will gradually expand by self learning.
Establishing nursing time database

- Time study technique was chosen as the best technique for establishing nursing time foundation

- A time study analyst observes Nurse / Expert Nurse / Head Nurse / Aid Nurse and measures the actual time taken to perform an activity
- The description for each activity and its duration are recorded in a time study form (Excel)

- The nursing activities were divided into 2 groups:

  - Direct nursing activities (A): tasks that can be connected to the assigned patient caring handled by his nurse such as: bandaging, medication, family interaction, patient hygiene etc.
  - Indirect nursing activities (B): tasks that can not be connected to the assigned patient caring handled by his nurse: unit related tasks (administration, clerical, team meetings etc.) co-ordination of care, breaks etc.

- Direct time distributions were derived for each level of nursing complexity (for 3 shifts)
A simulation model is developed using the Matlab software.

Patients classification, nursing time database, patient’s blend forecasting and 5 nursing allocation policies are the basic “ingredients” in this Matlab simulation program.

GUI (Graphic User Interface) to provide an easy way for inserting data which determine both the planning period and the nursing policy.

The simulator provides the following results:
1. FTE’s for the nursing mix
2. Total forecasted direct time
3. Total number of forecasted patients
Method implementation

Phase 1 => Backward assignment

- Manpower planning using current method, by Head Nurse
- At end of week re-planning, by simulator
- Evaluate the differences

Simulation

Sat Fri Thu Wed Tue Mon Sun Thursday
Planning day
Method implementation

Phase 2 => Parallel assignment

- Manpower planning, by Head Nurse and by Simulator - in parallel
- Evaluate the differences by the two planeres
Method implementation

Phase 3 => Assignment by simulator

- Manpower planning, by Simulator
- Evaluate outcomes
- Debugging

Simulation

Planning day

Thursday
Introducing Quality

Phase 4 => Plan according quality

- Plan according quality – use of quality measures while planing
- Evaluate results
Patient’s blend forecasting

- Nursing staff mix will depend on the blend and volume of patients admitted and applicable nurses - demanding complexity
- Manpower allocation procedure occurs in a 2 weeks planning horizon
- A model has been developed in order to forecast the patient mix
- For patients blend we define 3 patients ‘populations’:
  - Released – patients that were released during the shift from the ward to the community (home or institute), to other ward or to vacation
  - Admissions - patients that were accepted during the shift to the ward from another ward or from ER
  - Veterans – patients that are not related to the 2 above populations

- In order to forecast the patients blend, in a given shift, a 9 stages statistical analysis procedure was implemented
Patient’s blend forecasting

1. Define the parameters that need to be forecasted
   (1) Released patients
   (2) Admissions
   (3) Veteran patients

2. Mine historical data for the parameters
   Data from 1996 till 2006 was gathered

3. Divide the data to 2 groups: (1) Learning, and (2) Testing

4. Search for any patterns in the learning data
   Season patterns for the weeks days and exceptional patterns for some of the holidays periods were revealed

5. Select appropriate forecasting methods
   3 forecasting methods were selected: (1) Simple moving average; (2) Weighted moving average; and (3) Exponential smoothing

6. Select a measure for evaluation the forecasting goodness
   MAPE - Mean Absolute Percentage Error

7. Choose the best forecasting method
   This was done according to the value of the MAPE

8. Forecast to the test period
   A forecast was made to 2006

9. Evaluate the forecasts goodness
   This was done by the following measures: (1) Forecast average errors; (2) Forecast standard deviation error; and (3) Forecast error distribution
Quality of nursing care’s grade is a weighted average.
This will be calculated by the relative importance of each nursing core activity’s grade (AHP by Satty).

10 nursing core activities were selected:

<table>
<thead>
<tr>
<th>#</th>
<th>Core activity</th>
<th>#</th>
<th>Core activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Norton estimation</td>
<td>6</td>
<td>Wearing identifying brace</td>
</tr>
<tr>
<td>2</td>
<td>Pain estimation</td>
<td>7</td>
<td>Filling nursing report</td>
</tr>
<tr>
<td>3</td>
<td>Lansky estimation</td>
<td>8</td>
<td>Measuring pain in a daily basis</td>
</tr>
<tr>
<td>4</td>
<td>Falling risk estimation</td>
<td>9</td>
<td>Patients classification</td>
</tr>
<tr>
<td>5</td>
<td>Measuring pulse, temperature and blood pressure</td>
<td>10</td>
<td>Admissions ward explanation</td>
</tr>
</tbody>
</table>
The Quality equation

The result of a nursing core activity is the percentage of patients for whom the measured activity was fulfilled.

**Step 1 – converting the result of a nursing core activity to a nursing quality grade**

The nursing quality grade \( Q_i \) for a nursing core activity result \( R_i \) is computed as follows:

\[
Q_i = \begin{cases} 
R_i & R_i \geq 80\% \quad \forall i = 1,...,10 \\
0 & Otherwise
\end{cases}
\]

**Step 2 – computing the weighted average grade for the Quality of nursing care (Satty, 1994)**

The average grade for the quality of nursing care is computed as the sum of the products of each nursing quality grade \( Q_i \) and its relative weight \( W_i \)

\[
Q = \sum_{i=1}^{10} Q_i \cdot W_i
\]

The relative weight for each nursing quality grade determined by the Paired Comparisons technique.
Findings

- 2 Internal Wards (C and D) and 1 Surgery ward in the Sheba Med. Center were in the scope of a pilot study.
- Assignments, as determined for internal ward C and for internal ward D, are:

<table>
<thead>
<tr>
<th>Time</th>
<th>Internal ward C</th>
<th>Internal ward D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Head nurse</td>
<td>Nurse</td>
</tr>
<tr>
<td>Morning</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Evening</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Night</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
Patients blend

Based on the historical data an average percentages of each nursing level of care for both internal wards were calculated.
Nursing operation time – pilot study

<table>
<thead>
<tr>
<th>Shift</th>
<th>Nursing level</th>
<th>Distribution</th>
<th>n</th>
<th>Average (minutes)</th>
<th>Standard div.</th>
<th>Minimnal value</th>
<th>Maximal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>1</td>
<td>$12 + 18 \times \text{Beta}(0.644, 0.791)$</td>
<td>10</td>
<td>19.5</td>
<td>6.6</td>
<td>12.6</td>
<td>29.3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>$12 + 30 \times \text{Beta}(0.654, 0.862)$</td>
<td>20</td>
<td>24.9</td>
<td>9.4</td>
<td>12.3</td>
<td>41.7</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>$13 + \text{Weibull}(21.9, 1.18)$</td>
<td>18</td>
<td>33.9</td>
<td>16.0</td>
<td>13.6</td>
<td>65.6</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>$24 + \text{Gamma}(39.6, 0.709)$</td>
<td>7</td>
<td>52.1</td>
<td>27.2</td>
<td>24.3</td>
<td>97.9</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>$84 + 54 \times \text{Beta}(0.255, 0.348)$</td>
<td>4</td>
<td>101.0</td>
<td>24.9</td>
<td>84.1</td>
<td>138.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Morning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal (22.4, 7.54)</td>
<td>37</td>
<td>22.4</td>
<td>7.6</td>
<td>7.4</td>
<td>39.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$16 + 23 \times \text{Beta}(0.844, 1.11)$</td>
<td>21</td>
<td>26.1</td>
<td>6.7</td>
<td>16.2</td>
<td>38.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal (38.3, 17)</td>
<td>11</td>
<td>38.3</td>
<td>17.8</td>
<td>13.5</td>
<td>81.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uniform (23, 93)</td>
<td>5</td>
<td>56.1</td>
<td>28.5</td>
<td>23.1</td>
<td>92.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evening</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$1 \times \text{Triangular}(7, 15, 37)$</td>
<td>19</td>
<td>19.7</td>
<td>7.9</td>
<td>7.3</td>
<td>36.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal (22.4, 7.54)</td>
<td>37</td>
<td>22.4</td>
<td>7.6</td>
<td>7.4</td>
<td>39.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$16 + 23 \times \text{Beta}(0.844, 1.11)$</td>
<td>21</td>
<td>26.1</td>
<td>6.7</td>
<td>16.2</td>
<td>38.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal (38.3, 17)</td>
<td>11</td>
<td>38.3</td>
<td>17.8</td>
<td>13.5</td>
<td>81.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uniform (23, 93)</td>
<td>5</td>
<td>56.1</td>
<td>28.5</td>
<td>23.1</td>
<td>92.9</td>
</tr>
<tr>
<td>Night</td>
<td>1</td>
<td>Normal (5.06, 2.64)</td>
<td>24</td>
<td>5.1</td>
<td>2.7</td>
<td>0.8</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>$1 + \text{Weibull}(9.36, 1.88)$</td>
<td>40</td>
<td>9.3</td>
<td>4.7</td>
<td>1.9</td>
<td>20.8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>$5 + \text{Weibull}(7.28, 1.21)$</td>
<td>33</td>
<td>12.0</td>
<td>4.6</td>
<td>5.0</td>
<td>20.7</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Uniform (12, 79)</td>
<td>6</td>
<td>41.3</td>
<td>24.9</td>
<td>12.1</td>
<td>78.8</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>$9 + \text{Weibull}(30.8, 1.16)$</td>
<td>11</td>
<td>38.4</td>
<td>24.3</td>
<td>9.6</td>
<td>93.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shift</th>
<th>Admissions/Release</th>
<th>Distribution</th>
<th>n</th>
<th>Average (minutes)</th>
<th>Standard div.</th>
<th>Minimnal value</th>
<th>Maximal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>Admissions</td>
<td>$15 + \text{Exponential}(15.8)$</td>
<td>10</td>
<td>30.8</td>
<td>13.4</td>
<td>15.2</td>
<td>59.7</td>
</tr>
<tr>
<td></td>
<td>Release</td>
<td>$13 + 11 \times \text{Beta}(0.72, 0.779)$</td>
<td>7</td>
<td>18.3</td>
<td>4.2</td>
<td>13.3</td>
<td>23.6</td>
</tr>
<tr>
<td>Evening</td>
<td>Admissions</td>
<td>$15 + \text{Exponential}(15.8)$</td>
<td>10</td>
<td>30.8</td>
<td>13.4</td>
<td>15.2</td>
<td>59.7</td>
</tr>
<tr>
<td></td>
<td>Release</td>
<td>Normal (9.73, 5.13)</td>
<td>15</td>
<td>9.7</td>
<td>5.3</td>
<td>2.4</td>
<td>21.8</td>
</tr>
<tr>
<td>Night</td>
<td>Admissions</td>
<td>Uniform (24, 74)</td>
<td>10</td>
<td>48.8</td>
<td>16.6</td>
<td>24.1</td>
<td>73.5</td>
</tr>
</tbody>
</table>
Selecting the forecasting days

Number of nurses Vs. Quality of care (Internal ward C)

Choose the period time of forecasting (maximum is 14 days)

Choose the forecasting Month: January - Forward
Choose the forecasting Year: 2006 - Back

Click on the beginning day of forecasting

SUN MON TUE WED THU FRI SAT

Choose caring policy:
1. Nurse takes care of patients in level 1-5
2. Nurse takes care of patients in level 4-5
3. Head Nurse takes care of patients in level 1-3
4. Regular Nurse takes care of patients in level 1-3
5. Expert Nurse takes care of patients in level 4-5

See the forecasting results

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Selecting a month

Number of nurses Vs. Quality of care (Internal ward C)

Choose the forecasting Month:
- October
- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

Choose the forecasting Year:
- 2021
- 2022
- 2023
- 2024
- 2025
- 2026
- 2027
- 2028
- 2029
- 2030

Choose caring policy:
1. Nurse takes care of patients in level 1-3
2. Regular Nurse takes care of patients in level 1-3
Exped Nurse takes care of patients in level 1-3
Head Nurse takes care of patients in level 1-3
3. Regular Nurse takes care of patients in level 1-3
Exped Nurse takes care of patients in level 1-3
Head Nurse takes care of patients in level 1-3
4. Regular Nurse takes care of patients in level 1-3
Exped Nurse takes care of patients in level 1-3
Head Nurse takes care of patients in level 1-3
(except in the morning)
5. Regular Nurse takes care of patients in level 1-3
Exped Nurse takes care of patients in level 1-3
Head Nurse takes care of patients in level 1-3
(except in the morning)

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Selecting a predicted day

Number of nurses Vs. Quality of care (Internal ward C)

Choose the period time of forecasting (maximum is 14 days) 14 days
Choose the forecasting Month: October Back Forward
Choose the forecasting Year: 2006 Back Forward

Click on the beginning day of forecasting

October 2006

1 2 3 4 5 6 7
8 9 10 11 12 13 14
15 16 17 18 19 20 21
22 23 24 25 26 27 28
29 30 31

Beginning day for forecasting is 29-10-2006

Choose caring policy:
1. Nurse takes care of patients in level 1-5
2. Regular Nurse takes care of patients in level 1-3
   Expert Nurse takes care of patients in level 4-5
   Head Nurse takes care of patients in level 5-5
3. Regular Nurse takes care of patients in level 1-3
   Expert Nurse takes care of patients in level 4-5
   Head Nurse takes care of patients in level 5-5
4. Regular Nurse takes care of patients in level 1-3
   Expert Nurse takes care of patients in level 4-5
   Head Nurse takes care of patients in level 5-5
   (except in the morning)
5. Regular Nurse takes care of patients in level 1-3
   Expert Nurse takes care of patients in level 4-5
   Head Nurse takes care of patients in level 5-5
   (except in the morning)

See the forecasting results

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Selecting nursing policy

Number of nurses Vs. Quality of care (Internal ward C)

- Choose the period time of forecasting (maximum is 14 days)
- Choose the forecasting Month: October
- Choose the forecasting Year: 2006

Click on the beginning day of forecasting

October 2006

1. Nurse takes care of patients in level 1-5
2. Regular Nurse takes care of patients in level 1-3
   Expert Nurse takes care of patients in level 4-5
   Head Nurse takes care of patients in level 1-3
3. Regular Nurse takes care of patients in level 1-3
   Expert Nurse takes care of patients in level 4-5
   Head Nurse takes care of patients in level 1-3
4. Regular Nurse takes care of patients in level 1-3
   Expert Nurse takes care of patients in level 4-5
   Head Nurse takes care of patients in level 1-3
(except in the morning)
5. Regular Nurse takes care of patients in level 1-3
   Expert Nurse takes care of patients in level 4-5
   Head Nurse takes care of patients in level 1-3
(except in the morning)

Choose caring policy:

Policy #3
Policy #5
Policy #1
Policy #2
Policy #4
Policy #6

See the forecasting results
Findings of simulation - pilot study

Number of nurses Vs. Quality of care (Internal ward C) - Results

<table>
<thead>
<tr>
<th>Shift</th>
<th>Head Nurse</th>
<th>Expert Nurse</th>
<th>Nurse</th>
<th>Total direct time of care [min]</th>
<th>Beds in use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>1</td>
<td>1.5</td>
<td>3</td>
<td>1618</td>
<td>50</td>
</tr>
<tr>
<td>Evening</td>
<td>1</td>
<td>0.5</td>
<td>2</td>
<td>1174</td>
<td>51</td>
</tr>
<tr>
<td>Night</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>670</td>
<td>45</td>
</tr>
</tbody>
</table>

The results are due to Policy v3
Simulating – Wards C & D - morning shift
Simulating – Wards C & D - Evenening shift

- Number of Nurses
- Day of Forecasting
- Total Nurse in evening shift
- Morning shift
- Evening shift
- Night shift
- Total Nurse in morning shift
- Total Nurse in evening shift
- Total Nurse in night shift

Nursing Manpower Allocation - Assignments Vs. Quality
Simulating – Wards C & D - Night shift

Nursing Manpower Allocation - Assignments Vs. Quality
So far...